Gait & Posture 98 (2022) 128–133

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Comparison of gait parameters under single- and dual-task conditions between children with specific learning disorder and typically developing children☆

Emel Tasvuran Horata, Yunus Emre Kundakci *

Department of Physiotherapy and Rehabilitation, Afyonkarahisar Health Sciences University, Afyonkarahisar, Turkey

ARTICLE INFO

Keywords:
Learning disorders
Task performance
Gait

ABSTRACT

Background: Children with specific learning disorder (SLD) have some cognitive and postural stability problems compared to typically developing (TD) children. Their single and dual-task gait performance may be affected depending on these problems.

Research question: Are there any differences between the gait parameters of children with SLD and TD under single- and dual-task conditions?

Methods: A comparative-descriptive study was conducted among 35 children with SLD and 33 TD children. All participants were assessed for gait parameters using a custom wireless inertial sensor under single and dual-task conditions. In the dual-task gait tests, there were the following tasks: to carry a glass of water and to tell apart the color of the paper.

Results: The children with SLD exhibited gait deterioration in both single and dual-task gait ($p < 0.05$). Dual-task cost cognitive values were higher in children with SLD ($p < 0.05$).

Significance: This study highlights the worse gait performance of children with SLD under single- and dual-task conditions compared with TD children. However, interventions for their gait impairments are limited. At this point, SLD specialists can focus on multitasking to improve their walking skills.

1. Introduction

Specific learning disorder (SLD) is a common neurodevelopmental disorder that starts at school age and sometimes may not be recognized until adulthood. Its prevalence in school-aged children varies between 5% and 15% [1,2]. According to the criteria of the Diagnostic and Statistical Manual of Mental Disorders 5th edition, SLD is an umbrella term that covers difficulties in learning and using academic skills in one or more than one areas (reading, writing, and mathematics) and is often accompanied by delays in attention, language, and motor skills [2].

Cognitive impairment is an essential characteristic of children with SLD [3,4]. In SLD, central executive functions [5] and especially working memory [6,7] are impaired. Executive function allows individuals to take time to think and focus before taking action in case of new and unexpected difficulties. It has three essential components: the ability to shift between tasks (shifting), working memory updating, which is of primary significance in daily tasks (updating), and selectively participating in stimuli and inhibiting strong responses (inhibition) [8]. These components establish higher-order executive functions such as reasoning, problem-solving, and planning [9,10]. Executive function is essential for mental and physical health, quality of life [11], cognitive, social, and psychological development, and success in school and life [12]. Furthermore, there is a dynamic interference between executive function and motor areas, which may lead to gait disorders, especially during dual and multiple tasks [13].

Body balance during dynamic activities such as walking requires integrating multiple sensory, motor, and attention resources [14]. A possible impairment in the sensorimotor integration process due to deficiencies in vestibular, visual, proprioceptive, and tactile information causes weakened postural control [15]. Moreover, developing visual and spatial sensory limitations lead to an incorrect body scheme in working memory, executive function limitations in actualizing the

☆ This study was presented as an oral presentation at 5th Ege International Conference on Applied Sciences, May 21–22, 2022 – İzmir, Turkey

* Correspondence to: Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Zafer Saglik Kulliyesi, 2078th Street, No.: 3, Afyonkarahisar, Turkey.

E-mail address: emre.kundakci@afsu.edu.tr (Y.E. Kundakci).

https://doi.org/10.1016/j.gaitpost.2022.08.020
Received 13 December 2021; Received in revised form 8 August 2022; Accepted 30 August 2022
Available online 2 September 2022
0966-6362/

activity, and ultimately postural control disorder [16]. Considering the cerebellum's role in sensory processing, factors that affect the development of SLD have been recently associated with cerebellar deficits [17]. All these sensory process effects and postural control deficiencies in SLD may be associated with deterioration in basic motor skills such as walking and balance [14].

The dual-task paradigm is commonly used to analyze cognitive-motor interferences [18,19]. Performing two tasks simultaneously increases the additional demand for executive function and postural control [15]. This increase considerably affects the lower extremity joint kinematics during ambulation [20]. Especially walking while performing a working memory task changes gait characteristics and leads to a noticeably increasing gait variability [21]. This situation decreases gait performance while shifting from single-task to dual-task conditions and dual-task cost (DTC) [20].

We have not found any studies investigating the effect of single- and dual-task conditions on gait parameters in children with SLD. It is necessary to reveal the effects of additional tasks given while walking on the gait performance of children with SLD. According to Suhaili et al. [22], studies that compare children with SLD with typically developing (TD) children in terms of dual-task performance are needed to determine motor performance and functional mobility problems. Therefore, this study aimed to reveal possible differences by comparing the gait parameters of children with SLD and TD children under both single- and dual-task conditions (dual-task cognitive and dual-task motor). We hypothesized that DTC and gait performance would be worse in single and dual tasks in children with SLD than in TD children.

2. Materials and methods

2.1. Participants

Children aged between 6 and 17 years were included in this comparative descriptive study for an easier understanding of motor and cognitive tasks. The sample size was estimated using the sample calculation method. A priory analysis was conducted in G-Power 3.1.9.7 software to estimate the study's sample size using the sample calculation method [t-tests - Means: Wilcoxon-Mann-Whitney test (two groups)]. The power analysis of the effect size, which was accepted as d= 0.67, revealed that at least 80% power was obtained at the 95% confidence interval with at least 30 (total 60) participants in each group. Considering a 20% dropout rate, it was planned to include at least 72 individuals in the study. The study included 35 children with SLD (SLD group) who regularly attended a support education program twice a week in a special education institution and 33 age-matched TD children (TD group). The simple random sampling method was used in sample selection. Approval for the study was obtained from the Research Ethics Committee (Protocol number: 03.07.2020/333). Before the study was initiated, each parent or legal guardian read and accepted the informed consent stating the aim and content of the research in line with the Declaration of Helsinki.

2.2. Inclusion and exclusion criteria

The inclusion criteria for the SLD group were as follows: being aged between 6 and 17 years (for both genders) and being diagnosed with SLD.

The inclusion criteria for the TD group were determined in the following way: being aged between 6 and 17 years (for both genders) and being physically, mentally, and psychologically healthy. Furthermore, the participants were asked for a medical certificate from their family doctor indicating they were healthy.

The exclusion criteria for the SLD and TD groups were as follows: having any other acute/chronic orthopedic, neurological, or cardiovascular disorder that could affect the gait performance, having undergone surgery within the last six months, having a hearing disorder that could not be eliminated with a hearing aid and visual impairment that could not be eliminated with glasses, and having a body mass index (BMI) value of 25 kg/cm^2 or above.

2.3. Measurements

All participants' demographic data (age, gender, height, and weight) and dominant hand grip strengths were recorded. YEK collected demographic data and performed grip strength assessments. ETH performed gait assessments with G-Walk (G-Sensor, BTS Bioengineering S.p.A., Italy). The spatiotemporal gait parameters (gait speed, cadence, and stride length) and gait cycle parameters (gait symmetry index and propulsion) were assessed [23].

G-Walk is a validated and reliable wearable wireless sensor device with ICC values ranging from 0.799 to 0.977 in gait measurements of children with neurodevelopmental disorders [24]. The device can assess spatiotemporal parameters during walking by its accelerometer and gyroscope. The device has a software. For data analysis, all measurements are calculated based on an individual's height and movements. Therefore, prior to the assessment, the participants' age (day, month, year), height (cm), weight (kg), and leg length (cm) measurements were entered into the software in this study. The sensor was fixed at L4-L5 intervertebral disc level on the participants' clothing using a semi-elastic belt. The participants were asked to walk as naturally as possible on a 7-meter flat surface at their self-selected speed. The software reported the data automatically.

Two physiotherapists with an average of 11 years of clinical experience performed all assessments following a standard protocol. ETH has approximately five years of experience in gait analysis and dual tasks. Moreover, both researchers have training certificates in cognitive assessment. A decision on which researcher would perform the assessments was taken at a meeting held before the study.

The formal test was recorded after a trial test. Short periods of rest were allowed when needed (exhaustion, etc.). The researchers and participants were not blinded in this study. The gait assessment under single-task conditions did not include secondary cognitive or motor tasks. Two different methods were used for dual-task gait assessments, as described below. Both tasks were prepared without the need for any reading, writing, or mathematics skills to eliminate differences in academic skills.

1. While walking, the participants simultaneously told the colors of the cards. Seven 30 × 42 cm color cards (Rainbow colors: red, orange, yellow, green, blue, navy, and purple) were used for this task. During the task, the participants were asked to name the colored cards (consecutively) held at eye level from the opposite side as quickly as possible while walking. YEK showed the colored cards to the children (dual-task cognitive) (Fig. 2A).
2. Carrying a cup (4 cm diameter; 90 g curb weight) of water that was filled to 3 cm from the top on a tray while walking (dual-task motor) (Fig. 2B) [25].

Dual-task activities, such as walking while talking on the phone, require more attentional resources than single-task activities, such as walking on a flat ground. In the transition from single-task to dual-task conditions, the performance in each task making up the dual-task decreases. These performance decreases are called DTC [26]. In the study, the DTC was calculated as the absolute value of the difference between the scores of dual-task and single-task performances to measure the participants' dual-task abilities |DTC=dual-task performance − single-task performance| [26]. Accordingly, higher DTC values indicated the lower dual-task ability of the participants [19].

2.4. Statistical analysis

SPSS Version 26 (IBM Corporation, Armonk, NY) software program was used for statistical analysis. The Shapiro-Wilk normality test assessed whether the data were normally distributed. The Mann-Whitney U test was used in the group comparisons for gait (continuous) variables (gait speed, cadence, stride length, gait symmetry index, right propulsion, left propulsion) since the data were not normally distributed. Gait (continuous) variables were presented as median (IQR). Demographic (continuous) variables were given as mean ±standard deviation and median (minimum-maximum). Gender variables were expressed in numbers (percentile). The participants' demographic variables were compared by the Mann-Whitney U test or Pearson's chi-square test. $p < 0.05$ was accepted as a significant value.

3. Results

Eighty-two participants were contacted for the study, and 14 participants who did not meet the inclusion criteria (SLD group; 12 participants) and wanted to leave the study (TD group; 2 participants) were excluded from the study. A total of 68 participants (35 in the SLD group, 33 in the TD group) with a mean age of 11.9 ± 2.10 years and a mean BMI value of 17.25 ± 2.95 kg/cm^2 were included in the study. Fig. 1 shows the participant flow diagram.

No differences were found in the intergroup comparisons in terms of age (U= 429.000, p = 0.065), height (U=466.000, p = 0.171), weight (U=565.000, p = 0.878), BMI (U=456.000 p = 0.136), grip strength (U=26.500, p = 0.712), and gender (χ2 = 0.911, p = 0.340) (Table 1).

The SLD group had a significantly lower cadence (U=248.000, $p < 0.001$), right propulsion (U=215.000, $p < 0.001$), and left propulsion (U=216.000, $p < 0.001$) when compared to the TD group under single-task conditions. The SLD group had a significantly lower gait speed (U=261.000, $p < 0.001$), cadence (U=129.000, $p < 0.001$), gait symmetry (U=339.000, p = 0.003), right propulsion (U=157.500, $p < 0.001$), and left propulsion (U=141.000, $p < 0.001$) than the TD group under dual-task cognitive conditions. Moreover, the SLD group had a significantly lower cadence (U=217.000, $p < 0.001$), right propulsion (U=349.000, p = 0.005), and left propulsion (U=233.500, $p < 0.001$) than the TD group under dual-task motor conditions (Table 2).

The SLD group exhibited significantly higher DTC cognitive values for gait speed (U=329.500, p = 0.002), cadence (U=364.500, p = 0.009), stride length (U=349.000, p = 0.005), and gait symmetry (U=376.500, p = 0.014) than the TD group. Finally, there was no difference in all other DTC values between the two groups ($p > 0.05$) (Table 3).

4. Discussion

In this study, gait characteristics and DTC values were compared between children with SLD and TD children under single and dual-task conditions. Supporting our hypothesis, both single- and dual-task gait deteriorated in children with SLD. Additionally, children with SLD had higher DTC cognitive values.

Postural stability is task-dependent, and higher-level postural control requires adaptability to challenges of different gait tasks [27,28]. Therefore, this study investigated the effects of postural control disorders on gait parameters in children with SLD using the dual-task paradigm. Only one study assessed gait parameters in SLD but did not include the dual-task paradigm. The study determined that the gait speed of children with dyslexia was slower in very fast walking compared to the control group. The study results were consistent with our findings [29]. If gait parameters are impaired even in gait under single-task conditions, the presence of gait differences is predictable in more complex multitasking that requires multisensory input. Getchell et al. [30] compared gross motor coordination with the dual-task paradigm in children with and without learning disabilities. In complex tasks, children with learning difficulties showed a developmental delay in motor coordination compared to others [30]. Sensory input

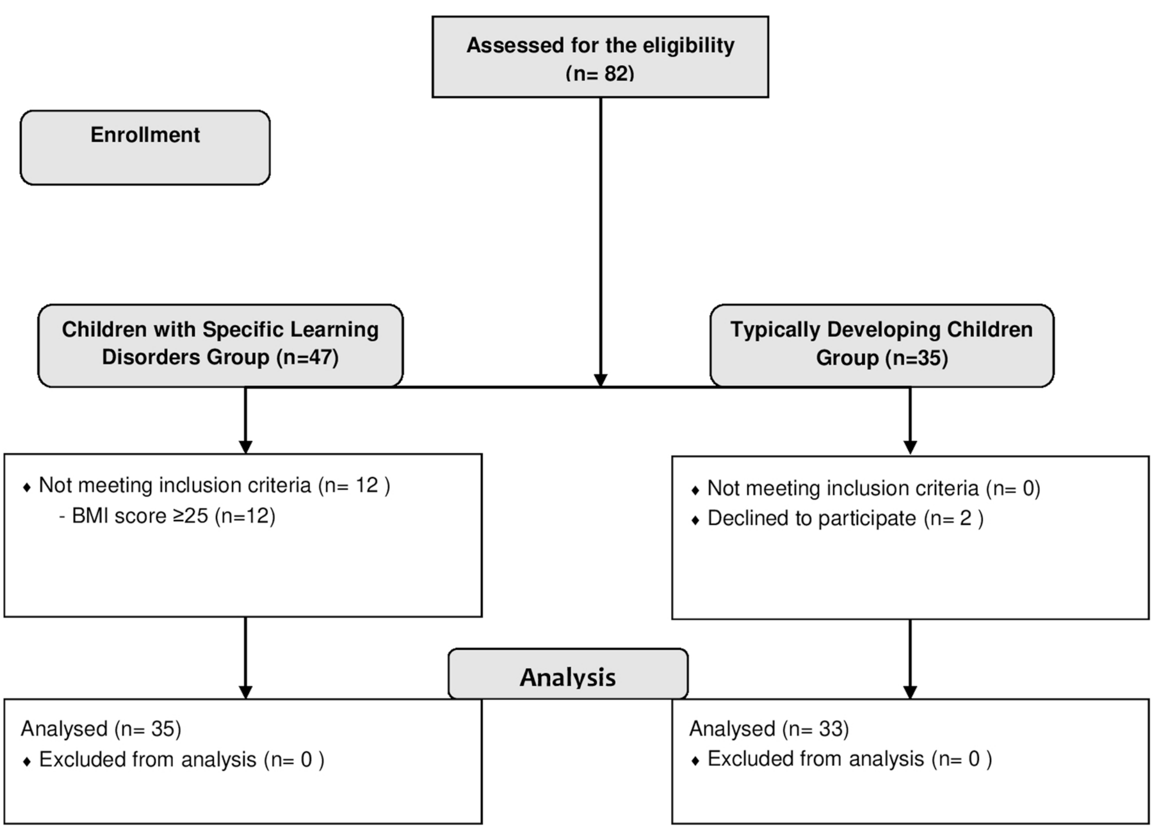

Fig. 1. Flow diagram of the study design.

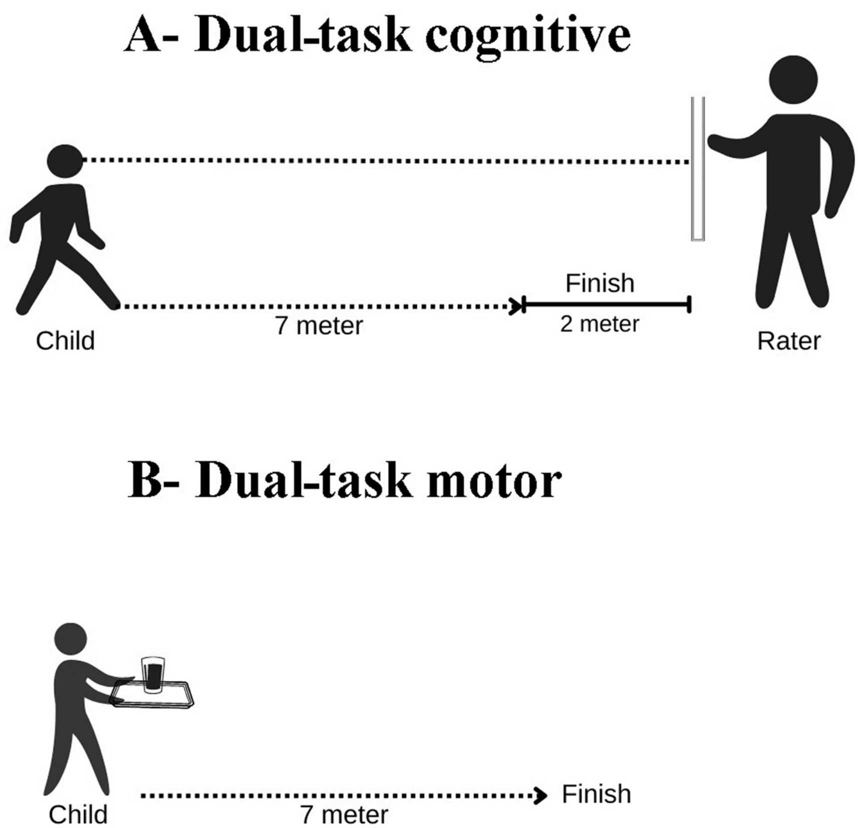

Fig. 2. Dual-task gait assessments. **A.** Dual-task cognitive. **B.** Dual-task motor.

Table 1
Demographic data of the participants.

	Groups				**U**	**p**
	SLD (**n = 35**)		TD (**n = 33**)			
	Mean+SD	**Median (min-max)**	**Mean+SD**	**Median (min-max)**		
Age (year)[u]	10.77 ± 2.18	10.5 (8–15)	11.64 ± 1.95	12 (7–15)	429.000	0.065
Height (cm)[u]	142.86 ± 14.52	142 (115–175)	146.48 ± 13.21	148 (118–172)	466.000	0.171
Weight (kg)[u]	36.29 ± 9.85	35.5 (20.6–65.4)	37.01 ± 11.74	34 (19–74)	565.000	0.878
BMI (kg/m^2)[u]	17.61 ± 2.96	17.63 (9.86–24.39)	16.87 ± 2.94	16.15 (13.49–24.96)	456.000	0.136
Grip Strength (kg)[u]	17.44 ± 5.62	16.83 (10.66–30.33)	15.93 ± 3.11	16.66 (12.66–19)	26.500	0.712
Female[k]	**n (%)**		**n (%)**		**χ2**	**p**
	11 (31.4)		7 (21.2)		0.911	0.340

[u]= variables are given as mean±standard deviation and median (minimum-maximum), Mann-Whitney U test was used; [k] = variables are given as number (%), Pearson's chi square test was used. BMI= Body mass index; SLD= Specific learning disorder; TD= Typically developing

deficits may explain the results obtained in the current study or the cerebellar deficit theory claimed in previous research. However, these results should be interpreted cautiously.

Postural control and gait have traditionally been considered automatic tasks using minimal attentional resources. Recent studies have shown that metacognitive domains such as attentional resources and working memory are associated with postural control and gait [14,31]. Attentional resources are limited and need to be shared in dual tasks. Sharing attentional resources decreases performance in each of the concurrent tasks. It was reported that executive functions such as working memory and attention, which are effective in performing complex multitasking, were impaired in SLD [32]. In this study, when an additional cognitive task was given to the SLD group, the performance decrease in gait was higher than that of the TD group. This situation may indicate that attentional resources shift from postural control to cognitive tasks in children with SLD. However, the two groups were similar according to DTC under dual-task motor conditions. We have a few ideas to clarify this. First, cognitive tasks are more complex than motor tasks for children with SLD. In other words, cognitive tasks have more attentional demands. Second, cognitive dual-tasks may have less automaticity and a stronger correlation with the ability to walk and balance compared to motor dual-tasks [33]. Legrand et al. [34] used the dual-task paradigm with reading cognitive tasks and found that the postural stability of children with SLD was worse than that of normal children. Karabulut et al. [35] reported that children with SLD performed worse than TD children in maintaining postural stability when a simultaneous motor task was added instead of a cognitive task. Contrary to the current study, they demonstrated that performing a concurrent cognitive task with postural stability did not affect postural stability in children with SLD. The difference between the results may be due to the differences in the chosen cognitive task. Visual inputs are a significant part of the movement and postural control. Using the visual cognitive task instead of the verbal fluency task may affect postural stability more. Goulème et al. [36] stated that a change in visual information was

Table 2
Comparison of single and dual task gait parameters between groups.

Condition	Gait parameters	Groups		U	p
		SLD (n = 35) Median (IQR)	**TD (n = 33) Median (IQR)**		
ST	Gait speed (m/s)	1.120 (0.37)	1.150 (0.40)	541.500	0.659
	Cadence (steps /min)	105.390 (20.06)	118.700 (14.43)	248.000	< 0.001 *
	Stride length (m/s)	1.240 (0.39)	1.200 (0.30)	445.000	0.104
	Gait symmetry index (%)	96.000 (2.80)	96.300 (1.75)	508.000	0.393
	Right propulsion (m/s^2)	7.300 (2.70)	9.700 (2.75)	215.000	< 0.001 *
	Left propulsion (m/s^2)	7.600 (2.20)	9.700 (3.40)	216.000	< 0.001 *
$DT_{cognitive}$	Gait speed (m/s)	0.800 (0.30)	1.190 (0.53)	261.000	< 0.001 *
	Cadence (steps /min)	87.000 (22.51)	111.790 (10.31)	129.000	< 0.001 *
	Stride length (m/s)	1.150 (0.37)	1.270 (0.61)	490.000	0.283
	Gait symmetry index (%)	94.200 (8.30)	96.400 (3.40)	339.000	0.003 *
	Right propulsion (m/s^2)	5.800 (2.00)	8.400 (2.10)	157.500	< 0.001 *
	Left propulsion (m/s^2)	5.500 (2.30)	8.800 (2.65)	141.000	< 0.001 *
DT_{motor}	Gait speed (m/s)	1.080 (0.43)	1.050 (0.26)	576.500	0.990
	Cadence (steps /min)	107.310 (11.78)	119.130 (20.45)	217.000	< 0.001 *
	Stride length (m/s)	1.190 (0.56)	1.060 (0.25)	420.000	0.053
	Gait symmetry index (%)	96.200 (2.50)	95.600 (3.35)	473.500	0.202
	Right propulsion (m/s^2)	7.400 (2.20)	8.600 (2.10)	349.000	0.005 *
	Left propulsion (m/s^2)	7.000 (1.60)	9.200 (2.45)	233.500	< 0.001 *

Statistical significance, $p < 0.05$ * . Mann-Whitney U test was used. The variables are given as median (IQR). ST= Single-task; DTcognitive= Dual-task cognitive; DTmotor= Dual-task motor; SLD= Specific learning disorder; TD= Typically developing. IQR= Interquartile range.

Table 3
Comparison of dual task costs between groups.

Condition	Gait parameters	Groups		U	p
		SLD (n = 35) Median (IQR)	**TD (n = 33) Median (IQR)**		
$DTC_{cognitive}$	Gait speed (m/s)	0.330 (0.62)	0.020 (0.38)	329.500	0.002 *
	Cadence (steps /min)	17.560 (23.10)	7.570 (8.65)	364.500	0.009 *
	Stride length (m/s)	0.165 (0.55)	0.090 (0.29)	349.000	0.005 *
	Gait symmetry index (%)	2.000 (8.20)	0.500 (3.30)	376.500	0.014 *
	Right propulsion (m/s^2)	1.700 (2.40)	1.200 (2.20)	509.500	0.404
	Left propulsion (m/s^2)	1.500 (2.40)	1.200 (1.95)	478.500	0.224
DTC_{motor}	Gait speed (m/s)	0.060 (0.42)	0.130 (0.28)	525.500	0.523
	Cadence (steps /min)	0.580 (12.69)	0.380 (8.70)	577.000	0.995
	Stride length (m/s)	0.080 (0.31)	0.150 (0.29)	546.500	0.704
	Gait symmetry index (%)	0.700 (2.70)	0.100 (3.75)	442.000	0.096
	Right propulsion (m/s^2)	0.000 (2.30)	1.000 (2.65)	323.500	0.052
	Left propulsion (m/s^2)	0.300 (2.60)	0.800 (3.40)	425.500	0.062

Statistical significance, $p < 0.05$ * . Mann-Whitney U test was used. The variables are given as median (IQR). DTCcognitive= Dual-task cost cognitive; DTCmotor= Dual-task motor; SLD= Specific learning disorder; TD= Typically developing. IQR= Interquartile range.

responsible for poor postural control in children. Such impairment was more obvious in children with SLD, most likely due to their inability to compensate for the sensory system via cerebellar integration.

Children with SLD have difficulties in specific academic skills such as reading, writing, and calculating. One limitation of the study is that diagnostic classification data for children with SLD were not specified (their difficulties in reading, writing, or calculating) because there were no records of the diagnostic classification in the special education institution where the study was conducted. This limitation of the study was partially overcome by designing the difficulty level of the cognitive task selected in the study so that it would not make a difference for the entire SLD population. Moreover, another limitation is that the sample had a wide age range, including children and adolescents. Gait assessment in more specific age groups may increase the reliability of results. Another limitation of the study is that the researchers and participants were not blinded.

Reading, writing, calculating, cognitive, and motor skills of children with SLD can be developed with support training programs, and they can be provided with opportunities similar to those of TD children in their academic and daily lives. However, today's support training programs primarily focus on academic success. Unlike other studies in the literature, this study emphasizes that dual-task gait differences, which have not been investigated before, and decreases in gait performance under cognitive dual-task conditions can occur in children with SLD.

In summary, the performance of children with SLD in dual-task gait decreased compared to TD children. Therefore, multitasking training should be included in the rehabilitation of children with SLD, and attention should be directed to postural control and gait in multitasking. Furthermore, it is recommended to focus on the sensories (visual, vestibular, and proprioceptive), which affect the development of postural control, in selecting tasks.

Funding

This work was supported by the Afyonkarahisar Health Science University Scientific Research Projects Commission [project no: 20. GENEL.016].

Declaration of Competing Interest

None

Acknowledgements

The authors are thankful for the support of the Afyonkarahisar Health Science University Scientific Research Projects Coordination Unit.

References

[1] K. Moll, S. Kunze, N. Neuhoff, J. Bruder, G. Schulte-Körne, Specific learning disorder: prevalence and gender differences, PLOS One 9 (2014), e103537, https://doi.org/10.1371/journal.pone.0103537.
[2] American Psychiatric Association (APA). 2021. Available at:<https://www.psychiatry.org/patients-families/specific-learning-disorder> [Accessed 10October 2021].
[3] J.M. Doherty, C. Belletier, S. Rhodes, et al., Dual-task costs in working memory: an adversarial collaboration, J. Exp. Psychol. Learn Mem. Cogn. 45 (2019) 1529–1551, https://doi.org/10.1037/xlm0000668.
[4] S. Wang, S.E. Gathercole, Working memory deficits in children with reading difficulties: memory span and dual task coordination, J. Exp. Child Psychol. 115 (2013) 188–197, https://doi.org/10.1016/j.jecp.2012.11.015.
[5] K. Landerl, B. Fussenegger, K. Moll, E. Willburger, Dyslexia and dyscalculia: two learning disorders with different cognitive profiles, J. Exp. Child Psychol. 103 (2009) 309–324, https://doi.org/10.1016/j.jecp.2009.03.006.
[6] G. Crisci, S. Caviola, R. Cardillo, I.C. Mammarella, Executive functions in neurodevelopmental disorders: comorbidity overlaps between attention deficit and hyperactivity disorder and specific learning disorders, Front. Hum. Neurosci. 15 (2021), 594234, https://doi.org/10.3389/fnhum.2021.594234.
[7] D.R. Hocking, S. Fritsche, H. Farhat, A. Atkinson, H. Bendak, J. Menant, Working memory is a core executive function supporting dual-task locomotor performance across childhood and adolescence, J. Exp. Child Psychol. 197 (2020), 104869, https://doi.org/10.1016/j.jecp.2020.104869.
[8] A. Miyake, N.P. Friedman, M.J. Emerson, A.H. Witzki, A. Howerter, T.D. Wager, The unity and diversity of executive functions and their contributions to complex, Front. Lobe" tasks: a latent Var. Anal., Cogn. Psychol. 41 (2000) 49–100, https://doi.org/10.1006/cogp.1999.0734.
[9] A. Collins, E. Koechlin, Reasoning, learning, and creativity: frontal lobe function and human decision-making, PLoS Biol. 10 (2012), e1001293, https://doi.org/10.1371/journal.pbio.1001293.
[10] L. Lunt, J. Bramham, R.G. Morris, et al., Prefrontal cortex dysfunction and 'Jumping to Conclusions': bias or deficit? J. Neuropsychol. 6 (2012) 65–78, https://doi.org/10.1111/j.1748-6653.2011.02005.x.
[11] W.A. Schraegle, J.B. Titus, Executive function and health-related quality of life in pediatric epilepsy, Epilepsy Behav. 62 (2016) 20–26, https://doi.org/10.1016/j.yebeh.2016.06.006.
[12] A. Diamond, Executive functions, Annu. Rev. Psychol. 64 (2013) 135–168, https://doi.org/10.1146/annurev-psych-113011-143750.
[13] D.R. Hocking, J.C. Menant, H.E. Kirk, S. Lord, M.A. Porter, Gait profiles as indicators of domain-specific impairments in executive control across neurodevelopmental disorders, Res. Dev. Disabil. 35 (2014) 203–214, https://doi.org/10.1016/j.ridd.2013.10.005.
[14] M. Woollacott, A. Shumway-Cook, Attention and the control of posture and gait: a review of an emerging area of research, Gait Posture 16 (2002) 1–14, https://doi.org/10.1016/s0966-6362(01)00156-4.
[15] A.L. Rosso, M. Cenciarini, P.J. Sparto, P.J. Loughlin, J.M. Furman, T.J. Huppert, Neuroimaging of an attention demanding dual-task during dynamic postural control, Gait Posture 57 (2017) 193–198, https://doi.org/10.1016/j.gaitpost.2017.06.013.
[16] M. Blanchet, C. Assaiante, Specific learning disorder in children and adolescents, a scoping review on motor impairments and their potential impacts, Children 9 (2022) 892, https://doi.org/10.3390/children9060892.
[17] R.I. Nicolson, A.J. Fawcett, P. Dean, Developmental dyslexia: the cerebellar deficit hypothesis, Trends Neurosci. 24 (2001) 508–511, https://doi.org/10.1016/s0166-2236(00)01896-8.
[18] N. Schott, Dual-task performance in developmental coordination disorder (DCD): understanding trade-offs and their implications for training, Curr. Dev. Disord. Rep. 6 (2019) 87–101, https://doi.org/10.1007/s40474-019-00163-z.
[19] E. Rabaglietti, A. De Lorenzo, P.R. Brustio, The role of working memory on dual-task cost during walking performance in childhood, Front. Psychol. 10 (2019) 1754, https://doi.org/10.3389/fpsyg.2019.01754.
[20] M.-I.B. Lin, K.-H. Lin, Walking while performing working memory tasks changes the prefrontal cortex hemodynamic activations and gait kinematics, Front. Behav. Neurosci. 10 (2016), https://doi.org/10.3389/fnbeh.2016.00092.
[21] W. Möhring, S. Klupp, R. Segerer, S. Schaefer, A. Grob, Effects of various executive functions on adults' and children's walking, J. Exp. Psychol. Hum. Percept. Perform. 46 (2020) 629–642, https://doi.org/10.1037/xhp0000736.
[22] S. Ibrahim, D. Harun, S. Baharudin, E.J.T. Hui, Motor performance and functional mobility in children with specific learning disabilities, Med. J. Malays. 74 (2019) 34–39.
[23] E. Ergin, S. Savci, B.O. Kahraman, et al., Three-axis accelerometer system for comparison of gait parameters in children with cystic fibrosis and healthy peers, Gait Posture 78 (2020) 60–64, https://doi.org/10.1016/j.gaitpost.2020.02.018.
[24] M.V. Yazıcı, G. Çobanoğlu, G. Yazıcı, Test-retest reliability and minimal detectable change for measures of wearable gait analysis system (G-walk) in children with cerebral palsy, Turk. J. Med. Sci. 52 (2022) 658–666, https://doi.org/10.55730/1300-0144.5358.
[25] H.-Y. Chen, P.-F. Tang, Factors contributing to Single-and Dual-Task timed "up & go" test performance in middle-aged and older adults who are active and dwell in the community, Phys. Ther. 96 (2016) 284–292, https://doi.org/10.2522/ptj.20140292.
[26] S. Schaefer, The ecological approach to cognitive–motor dual-tasking: findings on the effects of expertise and age, Front. Psychol. 5 (2014) 1167, https://doi.org/10.3389/fpsyg.2014.01167.
[27] G.M. Earhart, Dynamic control of posture across locomotor tasks, Mov. Disord. 28 (2013) 1501–1508, https://doi.org/10.1002/mds.25592.
[28] C.Y. Cho, G. Kamen, Detecting balance deficits in frequent fallers using clinical and quantitative evaluation tools, J. Am. Geriatr. Soc. 46 (1998) 426–430, https://doi.org/10.1111/j.1532-5415.1998.tb02461.x.
[29] R. Moe-Nilssen, J.L. Helbostad, J.B. Talcott, F.E. Toennessen, Balance and gait in children with dyslexia, Exp. Brain Res. 150 (2003) 237–244, https://doi.org/10.1007/s00221-003-1450-4.
[30] N. Getchell, S. McMenamin, J. Whitall, Dual motor task coordination in children with and without learning disabilities, Adapt. Phys. Act. Q 22 (2005) 21–38, https://doi.org/10.1123/apaq.22.1.21.
[31] E. Rabaglietti, A. De Lorenzo, P.R. Brustio, The role of working memory on dual-task cost during walking performance in childhood, 1754-1754, Front. Psychol. 10 (2019), https://doi.org/10.3389/fpsyg.2019.01754.
[32] C. Maehler, K. Schuchardt, Working memory in children with specific learning disorders and/or attention deficits, Learn. Individ. Differ. 49 (2016) 341–347, https://doi.org/10.1016/j.lindif.2016.05.007.
[33] J.K. Longhurst, M.A. Wise, D.J. Krist, C.A. Moreland, J.A. Basterrechea, M. R. Landers, Brain volumes and dual-task performance correlates among individuals with cognitive impairment: a retrospective analysis, J. Neural Transm. 127 (2020) 1057–1071, https://doi.org/10.1007/s00702-020-02199-7.
[34] A. Legrand, E. Bui-Quoc, K. Dore-Mazars, C. Lemoine, C.-L. Gerard, M.P. Bucci, Effect of a dual task on postural control in dyslexic children, PLoS One 7 (2012), e35301, https://doi.org/10.1371/journal.pone.0035301.
[35] M. Karabulut, B. Bas, B. Müjdeci, Evaluation of dual-task performance with Nintendo Wii-Fit plus in children with specific learning disabilities, Hear, Balance Commun. 19 (2021) 126–132, https://doi.org/10.1080/21695717.2020.1870822.
[36] N. Goulème, P. Villeneuve, C.-L. Gérard, M.P. Bucci, Influence of both cutaneous input from the foot soles and visual information on the control of postural stability in dyslexic children, Gait Posture 56 (2017) 141–146, https://doi.org/10.1016/j.gaitpost.2017.04.039.